

# EFFECT OF TRAPPED IONS IN A GATED TIME-OF-FLIGHT APPARATUS

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The time-of-flight (TOF) mass spectrometer is a versatile device for measurement of ionization phenomena produced by electron impact, multiphoton ionization, dissociative recombination, etc. Advantages in the TOF method lie in its large mass range, ability to measure entire mass spectra in a single cycle, and its ability to measure velocity distributions in a plasma.

In the present study a gated TOF apparatus<sup>1</sup> is used to determine velocity distributions of ions by measuring the flight time between two pulsed gates of known distance apart. Each gate consists of three meshes, with the two outermost meshes grounded. The center mesh is biased positively to repel ions, and opens momentarily by switching to ground. The outer meshes shield the flight region from the pulsing voltage. It was found that when the gate closed, ions still present in the gate structure were accelerated by the pulsed grid, thus modifying the velocity distribution being measured, and introducing a spurious TOF peak.

The TOF distribution in the final spectrum is determined by the original ion velocity distribution, and the transmission functions of the two gates. The velocity distribution  $D(t)$  is taken as a Maxwell-Boltzmann distribution converted from the velocity to the time domain

$$D(t) dt = 4\pi n \left( \frac{m}{2\pi kT_i} \right)^{3/2} \frac{L^3}{t^4} e^{-\frac{mt^2}{2kT_i}} dt \quad (1)$$

where  $L$  is the length of the flight tube, and  $m$ ,  $T_i$  and  $n$  the ion mass, temperature, and density, respectively. The TOF spectrum is calculated by convoluting Eq. (1) with the transmission function of the two gates. The overall flight time  $T$  is given by  $T = t_1 + t_2 + t_3$ , where  $t_1$  is the field-free time of the ion in the open gate,  $t_2$  is the time required for the ion to exit the gate while being accelerated by the pulsed electric field, and  $t_3$  is the remaining time in the flight tube. The distribution in Eq. (1), and the timing windows are divided into sampling bins, so the final spectral intensity  $I(t)$  can be expressed as

$$I(t) = \sum_i \sum_j \sum_k D(i,j,k) \quad (2)$$

The quantity  $D(i,j,k)$  is the component of velocity distribution in the  $j^{\text{th}}$  velocity bin, and the  $j^{\text{th}}$  time bin in  $G_1$ , transmitted to the  $k^{\text{th}}$  time bin in  $G_2$ . The time ranges in Eq. (2) are  $i$  ( $L/v_i$ ,  $L/v_i$ ),  $j$  ( $0, t_0$ ), and  $k$  ( $T + t_1 - t_0, T + t_1$ ), where  $t_1$  is the time of the  $j^{\text{th}}$  bin in  $G_1$ , and  $t_0$  is the gate duration of  $G_1$  and  $G_2$ . The last interval follows from the fact that the width  $t_0$  of  $G_2$  is convoluted with the width of  $G_1$ , so that the time window is extended.

Trapped ions produce a faster side peak to the TOF spectra, as shown in Fig. 1. The solid line is a result of modeling the trapped ion TOF distribution in terms of Eq. (1), the pulse risetime, gate voltage  $V_g$ , the mesh spacing, and TOF length  $L$ .

The onset and relative height of the side peak is dependent on the gating voltage and risetime of the pulsing electronics, while the relative intensity depends upon the sampled velocity and the ratio of mesh spacing to duration  $t_0$ . This dependence of onset TOF with  $V_g$  is shown in Fig. 2.

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## References

1. K.E. Martus, O.J. Orient, R.R. Hodges and A. Chutjian, *Rev. Sci. Instr.* (in press).
2. K. E. Martus, *et al*, *Rev. Sci. Instr.* (submitted).

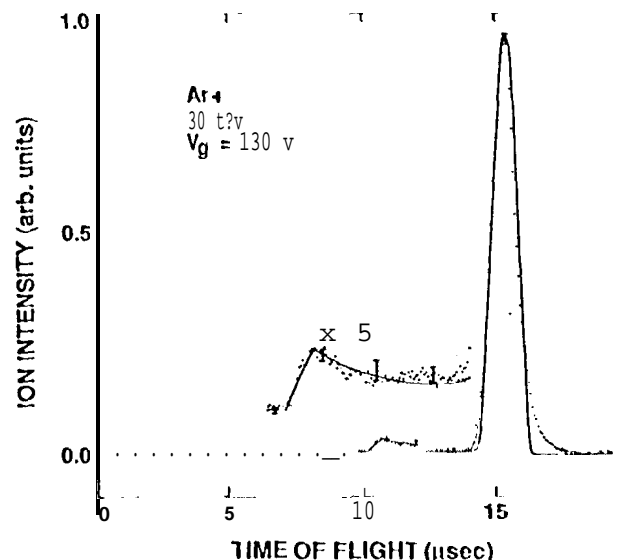


Fig. 1. TOF spectrum showing the side peak arising from faster, trapped ions. Experimental (•) and modeling results (—) are shown.

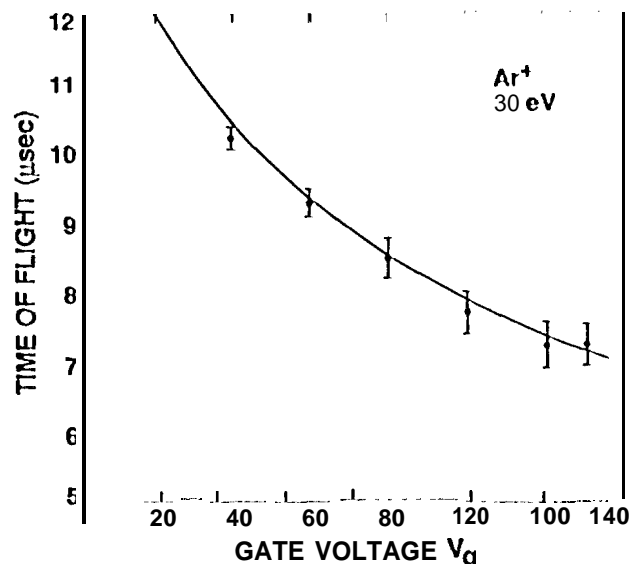


Fig. 2. Variation of the onset flight time vs  $V_g$ . Legend is the same as for Fig. 1.